Alignment of the ATLAS Inner Tracking System during LHC Run 2

LHCC poster session @ CERN 2/3/2016

Abstract

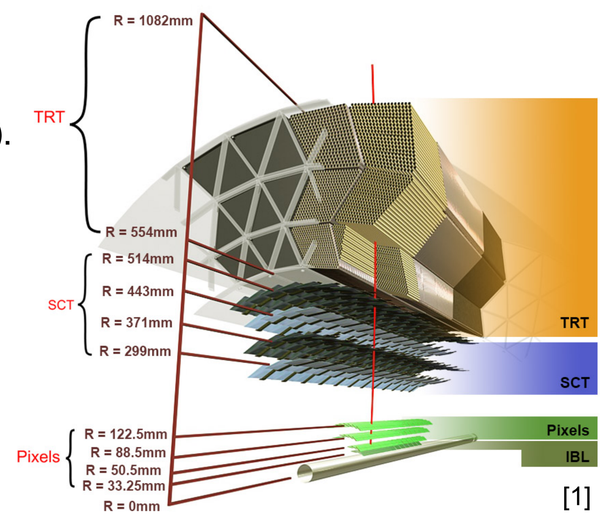
Assuring good tracking quality requires high precision alignment of the ATLAS Inner Detector. This poster presents the developments of the ID alignment during Run 2, notably the correction for IBL stave bowing and the use of external constraints to remove weak-modes.

The ATLAS Inner Detector

The Inner Detector is composed of 3 detector subsystems, the pixel detector, SCT and TRT. A new innermost layer of the pixel detector, the Insertable B-Layer (IBL) was installed during LS-1.

Pixel: Silicon planar pixel sensors
SCT: Silicon planar micro-strip sensors (Semiconductor Tracker)
TRT: Gaseous drift tubes (Transition Radiation Tracker)

IBL (Insertable B-Layer) : Made of silicon pixel planar modules ($|\eta| \lesssim 2.5$) and 3D modules ($|\eta| \gtrsim 2.5$). Pixel size is 50×250 μm. The IBL is located at 33 mm from the beamspot and significantly improves the d_0 and z_0 resolution.



[1]

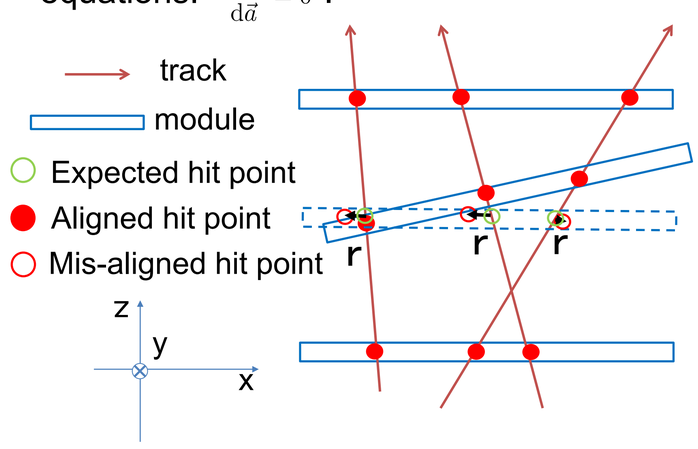
Alignment procedure

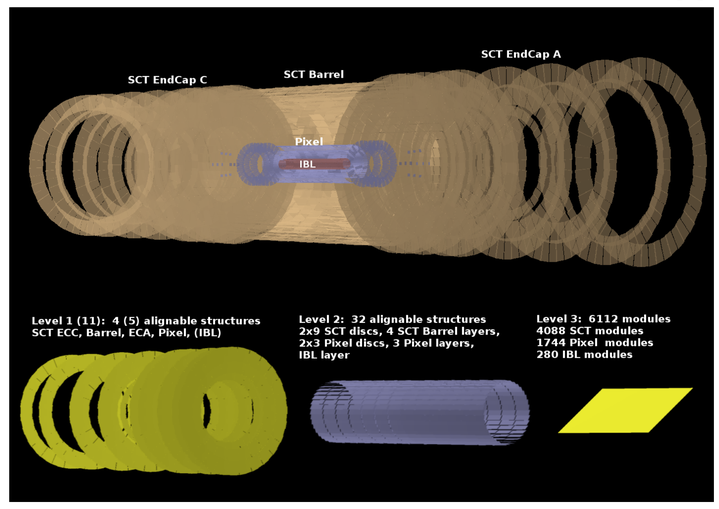
Alignment corrections to the assumed geometry are derived through the minimization of track χ^2:

$$\chi^2_i = \sum_i \left(\frac{|\vec{x}_i^{meas} - \vec{x}_i^{fit}|}{\sigma_i} \right)^2 = \sum_i \left(\frac{r(\vec{\tau}, \vec{a})}{\sigma_i} \right)^2$$

- *Track parameters* $\vec{\tau}$ (d_0, z_0, φ_0, θ, q/p)
- *Alignment parameters* $\vec{a}$ (3 translation + 3 rotation)
- *Expected track hit resolution* σ

Corrections to the assumed geometry are extracted by solving a linear system of equations: $\frac{d\chi^2}{d\vec{a}} = 0$. [2]



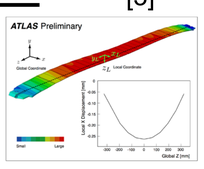


Alignment challenge I: IBL bowing

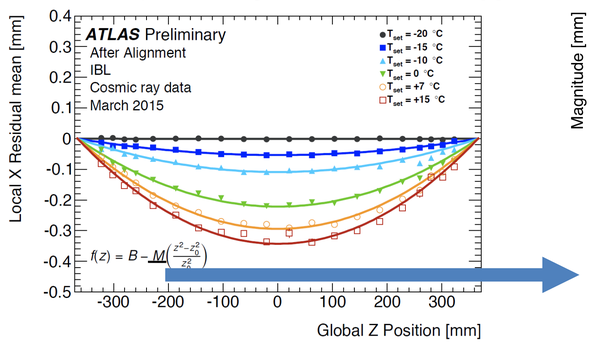
* Temperature dependent IBL stave distortion

- IBL staves found to bow depending on the stave/module temperature during the commissioning phase (M9) with cosmic events [3]. A new parameter is introduced to correct for it.

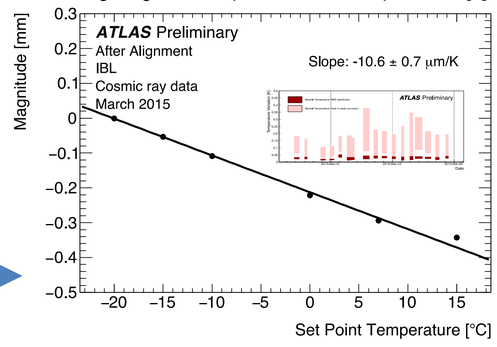
[3]



Local x residual dependence in global Z and temperature. [3]



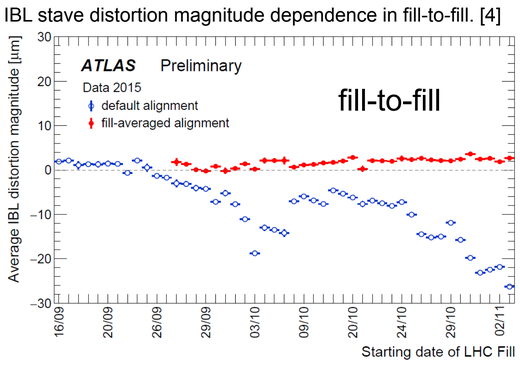
The bowing magnitude dependence on temperature. [3]



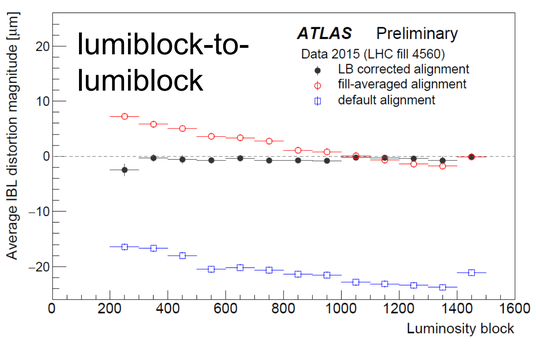
* Time dependent IBL bowing

- Since September 2015, the power consumption of the IBL modules has been unstable and correlated to the total dose. As a consequence, the bowing magnitude has been varying dynamically.
- A systematic time-dependent alignment correction with the granularity of 100 lumiblocks was introduced in ATLAS software.

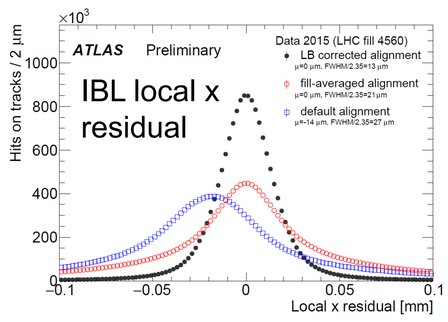
IBL stave distortion magnitude dependence in fill-to-fill. [4]



IBL stave distortion magnitude dependence in lumiblock-to-lumiblock. [4]



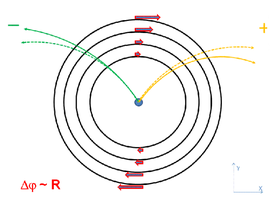
Local x residual distribution in default, fill-to-fill, and lumiblock-to-lumiblock. [4]



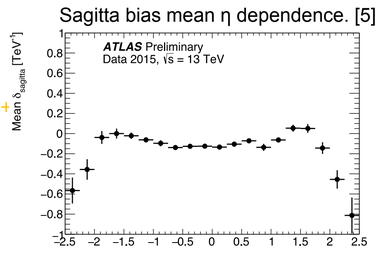
Alignment challenge II: weak-modes

- Weak-modes are systematic geometry deformations that introduce track parameter biases while leaving the track χ^2 unchanged.
- By adding independent constraints between tracks (e.g. Z→μμ and E/p for electron), some of the weak modes have been measured and corrected.

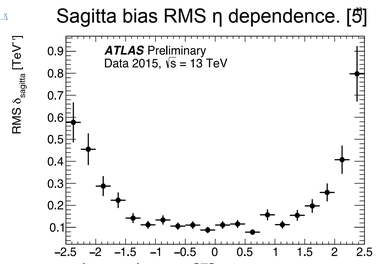
* Sagitta bias



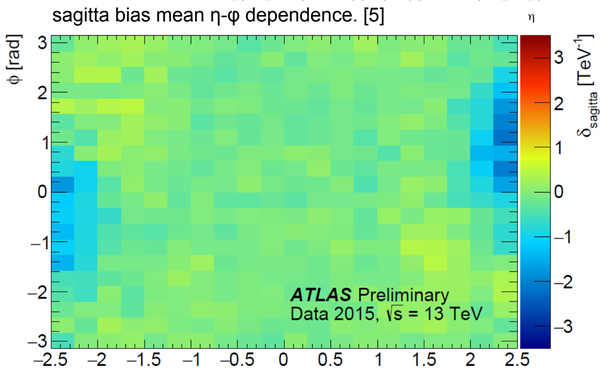
Sagitta bias mean η dependence. [5]



Sagitta bias RMS η dependence. [5]



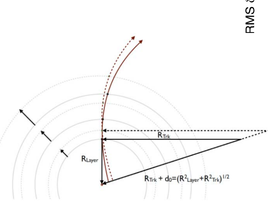
sagitta bias mean η-φ dependence. [5]



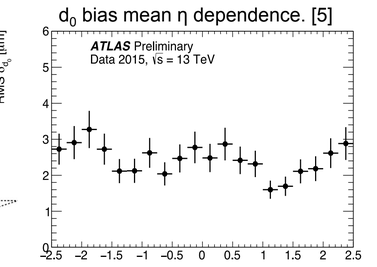
$$p_T \longrightarrow p_T(1 + q p_T \, \delta_{\text{sagitta}})^{-1}$$

The charge-asymmetric momentum bias is caused by the curl weak mode.

* Impact parameter bias



d_0 bias mean η dependence. [5]



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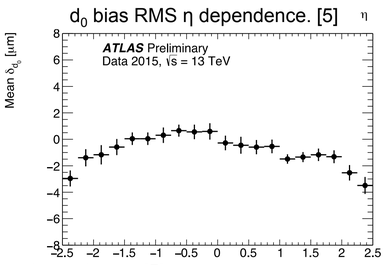

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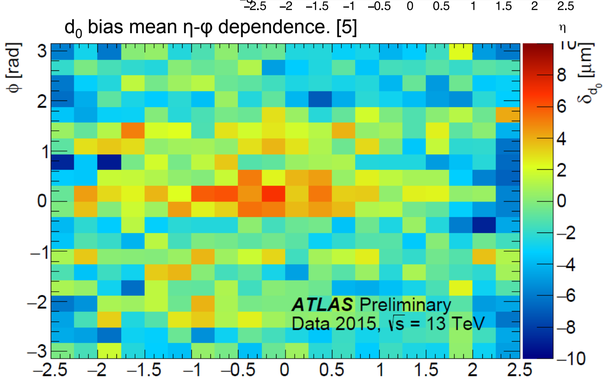

$$d_0 \rightarrow d_0 + \delta_{d_0}$$

Impact parameter biases are caused by the radial-expansion weak mode.

Summary

- There have been many challenges for ID alignment during the first year of Run 2 in 2015.
- Effects of time dependent IBL bowing have been successfully mitigated. The alignment framework has been updated to correct IBL bowing effects on a fill-to-fill as well as LB-to-LB basis. This is included in the baseline alignment procedure for the 2016 data taking.
- Track parameter biases due to weak-modes have been reduced using Z→μμ events. Remaining biases in data have been quantified.

References

[1] ATL-PHYS-PUB-2015-009, [2] ATL-PHYS-PUB-2015-031, [3] ATL-INDET-PUB-2015-001, [4] IDTR-2015-01, [5] ATL-PHYS-PUB-2015-051

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ATLAS EXPERIMENT